additional degree of freedom into the system, allowing for better optimization of $\eta_{implant}$.

[0085] An L matching network provides an additional degree of freedom with the extra shunt capacitor in the matching network. It can be used to transform the R_{in} to a higher or lower value depending on the topology and quality factor of the matching network. Here, the network is designed to transform R_{in} to match R_{piezo} at the frequency where PCE is optimal—concurrently maximizing both PCE and PME. For the L matching network scheme shown in the bottom of FIG. **7**, PME is maximized when Z'_{in} is the complex conjugate of Z_{piezo}. R_{in} is transformed down to a lower effective resistance by C_{L1} to match R_{piezo}. C_{L2} is then used to cancel out residual inductance from the piezoelectric receiver such that an optimal match is obtained. This transformation ratio is approximately bounded by the frequency dependent quality factor of the receiver, Q_{piezo}, defined as $Q_{piezo}=X_{piezo}/R_{piezo}$. The ratio is given as,

$$\frac{R_{in}}{R_{piezo}} < 1 + Q_{piezo}^2. \tag{8}$$

A meaningful transformation ratio thus can be achieved with larger Q_{piezo}. From the series circuit model as well as impedance measurement of the receiver, it can be observed that materials with high k_{33} result in higher Q_{piezo} in the middle of the IB; therefore, using an L matching network is more advantageous for material with high k_{33}. FIG. **17**A shows the measured reactance and Q_{piezo} of the PZT4 receiver in the IB. A comparison of optimized $\eta_{implant}$ for L matching, series matching, and non-adaptive systems is plotted in FIG. **17**B. An increase of as much as 20 percentage points in $\eta_{implant}$ is observed for the L matching network in comparison to series matching, while a nearly 50 percentage point efficiency boost is obtainable compared to a non-adaptive system operating at f_{sc}. The capacitances used in the network are about 2 pF to ~20 pF. Depending on the characteristics of the receiver, one can choose the appropriate matching networks to increase the total implant efficiency.

B5c) Measurement with Two Matching Networks

[0086] We performed wireless power transfer measurements for the power recovery chain at various load powers to verify the results obtained from ADS simulations for both matching networks. A full-wave bridge rectifier (same as the one used in simulation) and discrete capacitors for implementing matching networks are added onto the PCB board. Both the rectifier and programmable capacitors can be designed on-chip for further miniaturization. Different load resistors modeling P_{load} are connected off the board. The DC output voltage of the rectifier is measured through an oscilloscope. Measured efficiency at six different P_{load} for the three different configurations are shown in FIG. **17**B in circles. The measurement results are in good agreement with simulation, demonstrating the capability of using matching networks for efficient power transfer.

B6) Conclusion

[0087] We utilize off-resonance operation of mm-sized ultrasonic receivers to maximize power transfer efficiency of IMDs with a wide range of power levels. The piezoelectric receivers are designed to meet mm-dimensional requirements while also achieving a favorable impedance range for efficient power delivery. Materials and dimensions are identified as two of the major design variables to obtain the desired impedance range for typical implant applications. Theoretical analysis and experimental verification were performed to compare the performance of several different materials—PZT4, PZT5H, and $BaTiO_3$ were concluded to be well-suited for IMD powering and achieve high PCE. Using a capacitive-only matching network, $\eta_{implant}$ for various load powers can be maximized by utilizing the inductive band impedance of the receiver, and thus avoiding the use of conventional bulky inductors. Both series and L matching networks are analyzed and compared to typical resonance-based operation. The simulation and measurement results show significant increases in the total implant efficiency for a miniaturized implant with an ultrasonic receiver and a proper matching network.

1. A system for providing power to an implanted receiver, the system comprising:

1) an acoustic transmitter configured to provide acoustic radiation having an acoustic frequency f;

2) a receiver unit configured to be implanted into a biological subject, wherein the receiver unit is configured to receive the acoustic radiation and to be powered by the acoustic radiation;

wherein the receiver unit comprises

i) an acoustic transducer configured to receive the acoustic radiation and to provide an input electrical AC signal;

ii) an adaptively reconfigurable electrical impedance matching network configured to receive the input electrical AC signal and to provide an output electrical AC signal, wherein the electrical impedance matching network is capacitive without including any inductors;

iii) an electrical load; and

iv) a power recovery circuit configured to receive the output electrical AC signal and to provide DC power to the electrical load; and

3) a system controller;

wherein the system controller is configured to

a) alter one or more controlled system parameters including the acoustic frequency f, and

b) alter a configuration of the adaptively reconfigurable electrical impedance matching network,

responsive to changes in one or more system variables to control power delivery from the acoustic transmitter to the electrical load.

2. The system of claim **1**, wherein the acoustic transducer has an inductive band, and wherein the acoustic frequency is controlled by the system controller such that the acoustic frequency is within the inductive band.

3. The system of claim **1**, wherein the acoustic frequency is controlled by the system controller such that the acoustic transducer impedance is tuned to match an impedance as seen at an input of the adaptively reconfigurable electrical impedance matching network for the electrical load.

4. The system of claim **1**, wherein the acoustic transmitter is configured to provide continuous acoustic radiation, and wherein the acoustic frequency is varied continuously by the system controller.

5. The system of claim **1**, wherein the acoustic transmitter is configured to provide pulsed acoustic radiation, and wherein the acoustic frequency is varied from pulse to pulse and/or varied within pulses by the system controller.